Crude Oil Effects on Mortality, Growth and Feeding of Young Oyster Drills, *Urosalpinx cinerea* (Say)

BY

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(3 Text figures)

INTRODUCTION

Recently, pressures for oil pollution research have come from continued accidents, growth of tanker traffic, increased off-shore drilling, and plans for special terminal facilities in estuaries. Additionally, sewage, storm sewer and industrial effluents, tanker-shoreline storage, and small craft operations constitute chronic sources of oil pollution to coastal estuarine regions (Farrington & Quinn, 1973) which are particularly rich in marine life. The ability of sediments to store and slowly release petroleum hydrocarbons for several years (Blumer & Sass, 1972; Vandermeulen, 1977) plus the ability of filter feeding bivalves to concentrate hydrocarbons (Blumer *et al.*, 1970; Fong, 1976; Stegeman, 1977) pose special problems for benthic, carnivorous gastropods.

This paper is concerned with the effects of Nigerian crude oil on the survival and on the growth and predation rates of the common oyster drill *Urosalpinx cinerea* (Say, 1822) under laboratory conditions.

MATERIALS and METHODS

In all experiments Nigerian crude oil was absorbed onto kaolin clay particles at the ratio of 1 part oil to 9 parts clay by weight (10% oil-clay). The absorption technique is described by Noyes (1978) and proceeded by first dissolving the crude oil in pentane followed by adding the appropriate amount of kaolin clay (90% of oil plus clay), shaking the mixture thoroughly, and evaporating the pentane at 45° C under a vacuum until the mixture was dry. The resultant oil-clay was mixed thoroughly, covered and refrigerated at 5° C. From this a stock solution of 100 mg L^{-1} oil was prepared daily and diluted to provide the concentration of oil desired.

During the summer of 1975, egg cases of *Urosalpinx cinerea* were collected from the Delaware Bay tidal flats at the New Jersey Oyster Research Laboratory in Cape May and kept in the laboratory in running bay water until hatching. Groups of 10 snails were placed in 800 mL beakers at selected treatment oil levels (0 to 10 mg L^{-1} oil) in duplicates following procedures required for randomization. In a preliminary study it was found that kaolin clay alone at 100 mg L^{-1} (equal to the clay concentration in the highest concentration of oil-clay used in any experiment) did not inhibit growth of hatchling snails. Therefore, no clay-only controls were employed in the experiments presented here. Heights of hatchlings were measured to the nearest 0.01 mm (tip of siphonal canal to the apex of the spire) with a calibrated stereomicroscope at the beginning of the experiment and then on days 4, 8, 12 and 15. Mortalities were recorded on these days also. The bay water and oil-clay treatments were replaced daily with minimal disturbance to the snails' activity. Laboratory cultured oyster spat (1-7 days old) were supplied (in excess) as food.

In the fall of 1975 a similar experiment was conducted for 7 weeks with larger, juvenile snails dredged from the Delaware Bay. These were measured to the nearest 0.1 mm with a vernier caliper. In this experiment, the same procedures were followed as with the hatchlings except that there were 11 drills per 1000 mL beaker, the oyster spat were older (about 3 months), and each beaker was gently aerated. Water and cotton traps were used to remove any volatilized oil in the air source. Treatments consisted of bay-water and clay-only controls and oil concentrations between 0.5 and 3 mg L^{-1}. Oyster spat were supplied in excess at 7 day intervals. Heights were measured until week six. In order to gain insight as to why oil reduced the growth of hatchlings, the number of spat drilled and eaten was also counted for 7 weeks.

Analysis of variance (ANOVA), Student-Newman-Keuls (SNK), and simple linear regression (SLR) statistical procedures (Zar, 1974) along with procedures for combining probabilities (Sokal & Rohlf, 1969) were used to analyze the data.

RESULTS

Growth of Hatchlings

In calculating the mean heights of hatchlings at the end of the 3 growth experiments, duplicate data were combined due to the lack of significant differences between duplicates (Table 1). Mean initial heights ranged between 1.40 mm at 10 mg L^{-1} to 1.55 mm at 0.5 and 2 mg L^{-1} oil. After 15 day chronic exposures the mean heights of hatchlings were significantly less at 1 mg L^{-1} oil and greater in experiments one and two and at 2 mg L^{-1} oil and greater in experiment three.

Two-way ANOVA (experiment x concentration) followed by SNK testing of duplicate data revealed that increases in mean heights were not significantly different among experiments at similar oil concentrations. These data were thus combined in Figure 1 to give the time series of mean heights. Growth rates diverged after 4 days of oil exposure with growth of snails at 0.5 mg L^{-1} oil and in the

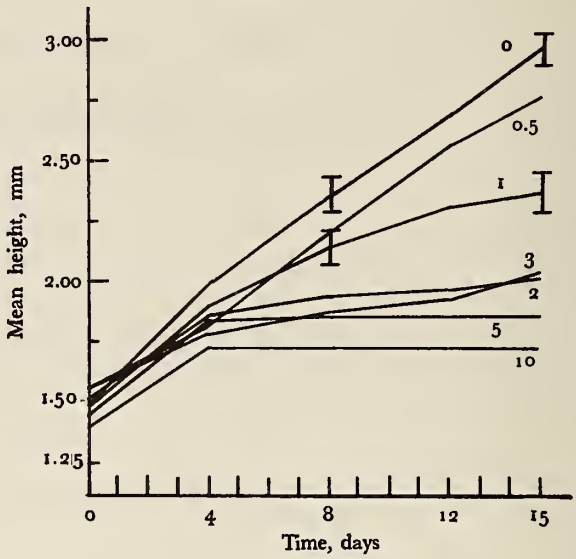

Figure 1

Urosalpinx cinerea

Mean height of hatchlings at different oil concentrations after 15 days. Data were averaged between duplicates and among experiments (Table 1) for each concentration. The 95% CI are illustrated for the control and for 1 mg L^{-1} oil (the lowest concentration of significant difference) on days 8 and 15. Concentration curves are indicated by numerical values in mg L^{-1}

Table 1

Urosalpinx cinerea. Heights of Delaware Bay hatchlings (x ± SE; duplicate data combined) in 3 experiments after 15 day exposures to different oil concentrations. n: number of hatchlings; F: F-value from one-way ANOVA; P_2: probability that the null hypothesis (H_0: all means are equal) for the F-test is true; P_1: probability that the treatment means do not differ from the control mean according to SNK testing; ns: not significant ($P > 0.20$).

	Mean heights (mm)								
Oil level	Experiment 1			Experiment 2			Experiment 3		
(mg l^{-1})	n	$\bar{x} \pm SE$	P_1	n	$\bar{x} \pm SE$	P_1	n	$\bar{x} \pm SE$	P_1
0	20	2.93 ± 0.18	–	20	3.17 ± 0.14	–	20	2.78 ± 0.18	–
0.5	–	–	–	–	–	–	20	2.76 ± 0.15	ns
1	20	2.90 ± 0.13	<0.01	20	2.20 ± 0.04	<0.01	20	2.61 ± 0.18	ns
2	–	–	–	–	–	–	20	2.04 ± 0.09	<0.03
3	–	–	–	20	1.95 ± 0.05	0.01	20	2.08 ± 0.08	<0.03
5	20	1.71 ± 0.03	<0.01	20	2.02 ± 0.06	<0.01	–	–	–
10	20	1.75 ± 0.03	<0.01	–	–	–	–	–	–
F	24.70			23.61			6.60		
P_2	<0.01			<0.01			<0.01		

control proceeding at a near constant rate while the growth of snails at 1, 2 and 3 mg L^{-1} oil declined. Growth of snails exposed to 5 and 10 mg L^{-1} oil was negligible after 4 days. Mean growth of hatchlings in the control (0.1 mm day^{-1}) was significantly greater than hatchling growth at 1 mg L^{-1} (0.06 mm day^{-1}, $P < 0.01$) and greater (0.03 and 0.02 mm day^{-1} at 2 and 10 mg L^{-1}, respectively, $P < 0.01$), when height increases were averaged over the 15 day experimental period.

Mortality of Hatchlings

Mortalities increased as oil concentration increased in each experiment, being significant ($P < 0.044$) in experiment two (Table 2). After the probabilities from each experiment's simple linear regression ANOVA were combined (Sokal & Rohlf, 1969), an overall significant ($P < 0.05$) effect between oil concentration and mortality was evident. Mean percent mortalities ($\bar{X} \pm SE$) among experiments increased from $38.3 \pm 6.0\%$ in the control to $61.7 \pm 9.1\%$, $67.5 \pm 7.5\%$ and $75 \pm 5\%$ at 1, 3 and 10 mg L^{-1} oil, respectively.

Growth of Juveniles

As for hatchlings, mean height data between duplicates were combined due to lack of significant differences. Initial mean heights ranged from 10.4 mm at 2 mg L^{-1} to 10.6 mm in the bay-water control (Figure 2). Growth of juvenile snails in the bay-water control, the clay-only control, and at 0.5 mg L^{-1} oil proceeded at nearly constant and equal rates (0.5 mm $month^{-1}$) during the 6 week expo-

Table 2

Urosalpinx cinerea. Mortality figures of Delaware Bay hatchlings after 15 day exposures to different oil concentrations. Means between duplicates with the range in parenthesis are given. n: number of hatchlings; F: F-value from the simple linear regression ANOVA; P_1: probability that the null hypothesis (H_0: slope = 0) for the SLR F-test is true; P_2: combined probability (Sokal and Rohlf, 1969) that the null hypothesis is true.

Oil level	Number of deaths					
	Experiment 1		Experiment 2		Experiment 3	
(mg l^{-1})	n	$\bar{x}$ (range)	n	$\bar{x}$ (range)	n	$\bar{x}$ (range)
0	10	4 (3 - 5)	10	3 (2 - 4)	10	4.5 (3 - 6)
0.5	–	–	–	–	10	4.5 (3 - 6)
1	10	7 (6 - 8)	10	6 (4 - 8)	10	5.5 (3 - 8)
2	–	–	–	–	10	6 (4 - 8)
3	–	–	10	6.5 (5 - 8)	10	7 (6 - 8)
5	10	6.5 (6 - 7)	10	8 (8 , 8)	–	–
10	10	7.5 (7 - 8)	–	–	–	–
F	3.21		6.73		2.07	
P_1	<0.14		<0.04		<0.22	
P_2	<0.042					

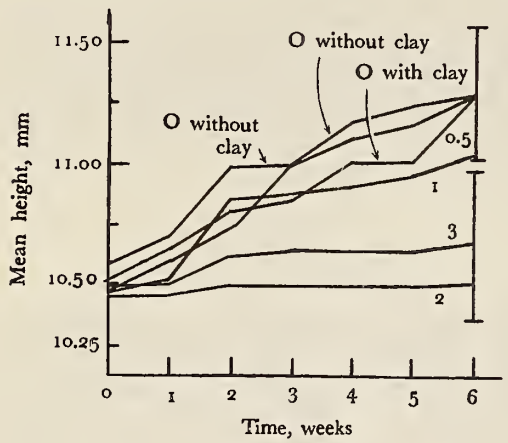

Figure 2

Urosalpinx cinerea

Mean height of juvenile snails for combined duplicates at different oil concentrations after 6 weeks. The significant differences between the two controls and 2 and 3 mg L^{-1} oil after 6 weeks is indicated by 95% CI at the former (bay-water and clay-only controls' mean heights were both equal to 11.3 mm) and at 3 mg L^{-1} oil. Concentration curves are indicated by numerical values.

w/ = with w/o = without

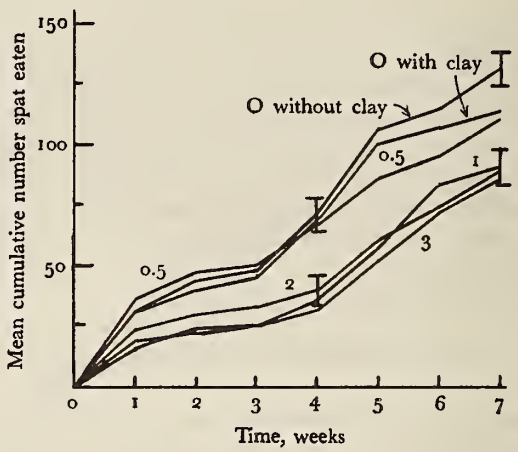

Figure 3

Urosalpinx cinerea

Mean cumulative oyster spat consumption between duplicates. The significant differences between the bay-water control and 1 mg L^{-1} oil and greater are indicated by 95% CIs at the former and at 2 mg L^{-1} oil on weeks 4 and 7. Concentration curves are indicated by numerical values.

w/ = with w/o = without

sure period. Growth of snails at 1 mg L^{-1} oil was also fairly constant (except week two) but averaged less (0.36 mm $month^{-1}$). Mean growth of snails at 2 and 3 mg L^{-1} oil was minimal (0.03 and 0.07 mm $month^{-1}$, respectively) and significantly less ($P < 0.01$) than growth of snails in the controls.

Feeding of Juveniles

The cumulative number of oyster spat eaten per snail per week (mean values) at various oil concentrations are given in Figure 3. Mean spat consumption by snails in the bay-water control, the clay-only control and at 0.5 mg L^{-1} oil diverged from those of snails exposed to 1 mg L^{-1} oil and greater during the first week. The divergence continued at a slower rate during the following 3 to 4 weeks. After 4 weeks mean cumulative spat consumption at 1 mg L^{-1} oil and greater was significantly ($P < 0.01$) less than the control values. After week 5 the snails exposed to the higher oil concentrations fed at the same rate as the control snails; however, the significant differences were maintained.

Mortality of Juveniles

There were no oil related mortalities during the 7 week exposure period. One snail died in the clay-only control and two snails died in each of the other treatments.

DISCUSSION

Moore & Dwyer (1974) reported in a literature review that soluble aromatic derivative levels between 1 to 100 mg L^{-1} are lethal to marine gastropods, and that chronic sublethal dosages up to 1 mg L^{-1} disrupt the physiological and behavioral activities of marine organisms including gastropods. In this study, chronic exposure of *Urosalpinx cinerea* hatchlings to 1 mg L^{-1} dosages of Nigerian crude oil and greater caused a significant reduction in the growth rates after 8 days ($P < 0.05$) when compared to control snails. Growth of the older juvenile snails was reduced significantly at 2 mg L^{-1} oil and greater after 6 weeks ($P < 0.05$) and there were no oil related deaths. However, there were significant ($P < 0.05$) oil related mortalities for hatchlings. Byrne & Calder (1977) also report growth reduction and mortality for *Mercenaria* sp. larvae after 6

and 10 day exposures to various crude and refined oils. My results also corroborate other recent reports of oil-induced growth reduction and mortality (Krebs & Burns, 1977; Noyes, 1978; Vandermeulen, 1977).

Unfortunately, no feeding data were collected during the hatchling experiments; however, the feeding data from the juvenile snail growth experiment are of considerable interest. Reductions in feeding of marine organisms exposed to similar oil concentrations, as occurred during the first 5 weeks of my experiment, are commonly reported (Atema, 1977; Eisler, 1975; Gilfillan, 1975; Wells & Sprague, 1976). Although the oyster spat were pumping (evident from pseudofeces), oil can interfere with chemotaxis (Atema, 1977; Boylan & Tripp, 1971; Jacobson & Boylan, 1972). However, snails at 1 mg L^{-1} oil and greater fed at about the same rate as did snails in the controls after 5 weeks, although they did not grow nearly as much. This may be due to increased respiratory demands resulting from exposure to oil. Gilfillan (1975) found that carbon assimilation into tissue decreased while respiration increased when the bivalves *Mytilus edulis* and *Modiolus demissus* were exposed to crude oil extracts and Vandermeulen (1977) reported similar results for individuals of the bivalve *Mya arenaria* inhabiting the location of an oil spill. Exposure of the gastropod *Littorina littorea* to Bunker C crude oil increased its respiration rate (Hargrave & Newcombe, 1973).

H. Haskin and G. Noyes (Noyes, 1978) prepared the 10% oil-clay (which was made available to me) for their extensive work on the effects of various petroleums on the survival, growth and behavior of the oyster *Crassostrea virginica*. They reasoned that organisms inhabiting turbid estuaries (which includes *Urosalpinx cinerea*) such as the Delaware would be exposed to oils absorbed onto fine particles. Their belief has been supported by reports that oil will absorb onto clay and other suspended particles (*e.g.*, detritus and plankton) in saline water (Bassin & Ichiye, 1977; Lee *et al.*, 1978; Meyers & Quian, 1973) and by a report that most of the hydrocarbons found in the water column of the Delaware Bay are associated with particles (Whipple & Pattrick, 1977; cited by Noyes, 1978). Noyes (1978) reported that 10% oil-clay (Nigerian crude) caused significant increases in mortality and a reduction in feeding by adult oysters (*C. virginica*) after 5 to 10 week chronic exposures to 0.3 mg L^{-1} oil and greater. I know of only one other study using oil absorbed onto clay; Fossato & Conzonier (1976) reported significantly increased mortalities (15 to 70%) of the bivalve *Mytilus edulis* when exposed to 0.2 to 0.4 mg L^{-1} diesel fuel absorbed onto kaolin clay particles.

I did not analyze for actual aqueous concentrations of hydrocarbons or the chemical composition of the Nigerian crude oil. Noyes (1978) reported an approximate 60% recovery (range: 20 to 100%) of the adsorbed Nigerian crude after it was added to sea water. He suggested that the difference could be due to loss of volatile components as well as possible incomplete removal of hydrocarbons from kaolin using Gruenfeld's (1973) analysis. An extrapolation of Anderson *et al.*'s (1974) data on the percent dissolution of 2 other crude oils (Kuwait and Louisiana crudes) suggest that if they were added to saline water at 10 mg L^{-1} and less, nearly 100% would dissolve. Their data also show that the most toxic components of crude oils (the aromatics) would be enriched in solution relative to n-paraffins of similar molecular weight when compared to the parent crude.

The above discussion lends insights into the probable behavior of the oil-clay in hatchling experiments which were not aerated. Concerning the experiment with juvenile snails which included gentle aeration the oil concentration probably decreased over time. Anderson *et al.* (1974) reported 88% and 89% reductions in total hydrocarbons for oil-in-water dispersions of Kuwait and Louisiana crudes, respectively, after 24 hours aeration. Reductions in total n-paraffins (95% and 97%) exceeded reductions in total aromatics (52% and 69%) during this time. Bigford (1977) reported a 50% reduction in dissolved hydrocarbons after 24 hours with aeration.

Although one must be cautious in translating the results of a laboratory study such as this to the estuary, it does indicate that behavioral and physiological mechanisms of the oyster drill may be significantly altered by chronic exposures to a crude oil adsorbed on clay. The chronic oil concentrations used in these experiments are realistic especially when one considers spills and port areas and the tendency of sediments to store and release petroleum hydrocarbons for several years (Blumer & Sass, 1972; Farrington, 1977; Krebs & Burns, 1977; Sanders, 1977; Vandermeulen, 1977).

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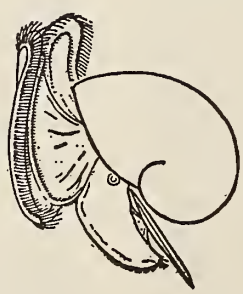
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